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AN OVERVIEW ON INTEGRATING INTERFACE MANAGEMENT AND BUILDING INFORMATION MANAGEMENT SYSTEMS

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Abstract: Complex capital projects such as rapid transit systems, power plants, refineries and port facilities are hard to manage since those projects are generally executed by project participants who have different specializations and may also be located in geographically different places. In these type of projects, the complexity of tracking coordination between project stakeholders, controlling design and engineering processes, and monitoring project health requires project participants to use advanced project management techniques. Interface Management Systems (IMS) and Building Information Modelling (BIM) are advanced project management systems increasingly used for complex projects. IMS is used to create interface points and agreements among different project participants for tracking and solving interface related problems between them, while BIM provides a digital 3D representation of the project where users can store data on the elements of a 3D model. Although these sophisticated new techniques are providing better visualization and coordination for project managers on complex projects, they need to be integrated with each other and with CPM systems to enable more-effective project management. The objective of this paper is to develop a framework for the integration of IM and BIM systems, in order to create better coordination and communication between project participants over interface related problems in the project definition and design phases. First, IM and BIM systems, and how they benefit project participants are briefly explained. Then, the proposed framework, which is based on connecting interface points and interface agreements of an IM system with related BIM elements on the 3-D model is introduced. Finally, the functionality of proposed framework is partially validated through an example.

1 Introduction

Complex capital projects are huge undertakings with inherent complexities. The large numbers of project stakeholders, overlap of construction activities, variety of technologies employed, several trades that are involved, and the uncertainty and risk in the design, procurement, and construction of such projects creates technical, organizational, and social complexities. Severe competition and increased demand for faster delivery while maintaining high-quality engineering standards further adds to these complexities. Successful delivery of such projects relies on highly effective coordination and timely communication among many project stakeholders, real-time tracking and measurement of project progress and performance, early detection of risk, and minimizing but rapidly adapting to imperative change.

Conventional project management approaches such as CPM scheduling and earned value analysis remain the backbone of modern project management; however, today's complex projects rely on additional sophisticated systems that employ iterative methodologies. Two important approaches for managing more complex projects are Building Information Modelling (BIM) and Interface Management (IM). The link between BIM and conventional project management approaches is well established through the connection of schedule and cost data with 3D BIM objects, and that results in 4D and 5D BIM Models. Also, the connection between IM and schedule control has recently been developed by Shokri in 2014 (Shokri, 2014). However, the link between BIM and IM has yet to be established. The term "BIM" will be used in this paper to refer to this whole class of systems.

Visualization of the IM system by linking BIM and IM systems would help project participants better coordinate the project and communicate on interface-related problems. Although implementing an IM system in the early phases of complex projects should generally result in better management in terms of cost, schedule, and scope, in practice, not all IM implementations have concluded successfully. Some reasons given for specific interface management problems were "Lack of communication and coordination between project parties", "Incomplete design or project plan", "Poor definition of project interfaces", "Mismanagement of responsibilities", "Misunderstanding of integration and fusion between project parties as a system components", and "Unclear details in the drawings", etc. (Shokri 2014). Many of these problems are related to communication, coordination, and visualization problems that can be solved by connecting an IM system with a BIM system in the early phases of a project.

This paper is part of an ongoing research project effort to determine the best ways of measuring project health and progress. The aim of this paper is to introduce the conceptual framework for integrating IM and BIM systems to create better coordination and communication between project participants and so avoid interface-related problems in the project definition and design phases. Presenting quantitative results from the proposed framework at this time, other than the quantities of the model itself, is beyond the scope of this conference paper.

2 Literature Review

2.1 Interface Management (IM)

The term "interface" has several different definitions and classifications in literature. One of the initial definition was proposed by Wren (1967) as "the contact point between relatively autonomous organizations which are interdependent and interacting as they seek to cooperate to achieve some larger system objectives". Over the years, several different researchers suggested numerous definitions for "interface". Today many researchers consider it as "a common boundary or interconnection between independent but interacting systems, organizations, stakeholders, project phases and scopes, and construction elements" (Shokri, 2014; P. Harrison, B. A. Hamilton, 2004; Chen et al., 2007; Healy, 1997; Lin, 2009; Lin, 2012; Morris, 1983; Stuckenbruck, 1988; Wren, 1967).

Mainly interfaces occur when a project divided into several sub-projects undertaken by different organizations. These interfaces can be soft or hard, and external or internal. Information exchanges between project participants such as design criteria, clearance requirements, or utility needs between engineering delivery teams or between a delivery team and an external party are examples of soft interface deliverables. Examples of hard interfaces include physical connections between two or more components or systems such as structural steel connections, pipe terminations, or cable connections. An interface within a single contract or scope of work would be an internal interface, whereas if it occurs between contracts or scopes of work, then it would be an external interface (Shokri, 2014).

In 2014, CII published an implementation guideline for IM where definitions of interface, interface management, and typical elements on an IM system hierarchy, provided. According to that guideline, the definition of an IM System is "the management of communications, relationships, and deliverables among two or more interface stakeholders". Hierarchical structure of and IM system consist of three elements which are namely, interface points (IPs), interface agreements (IAs), and interface agreement deliverables (IADs). An IM system may include many IPs. Each IP can include many IAs, and each IA can include many IADs. A typical megaproject may include tens of thousands of IADs. By managing interfaces during the definition and design phases of complex capital projects, rework can be reduced, and project cost and schedule performance can be improved substantially, because exchange of insufficient, wrong or delayed information between project participants is minimized (Chan, Leung 2004, Shokri 2014).

In the literature, an increasing number of studies that deal with the IM System definition, interface problems, and web based IM system platforms, can be found. Some of these studies related with interface definitions and interface problems, are summarized according to their chronological order afterwards. In 2003, Pavitt and Gibb explained the need for IM systems in building projects and provided a software system that helps project stakeholders to manage cladding interfaces (Pavitt, Gibb 2003). Harrison and Hamilton (2004) provided an overview of an IM system for railroad and rail transit systems. Interface problems that can occur on different types of contracts in railway projects, interface control process illustrations, and risks of IM systems on rail transit projects are explained (P. Harrison, B. A. Hamilton 2004). In 2006, Chua and Godinot introduced the Work Breakdown Structure (WBS) matrix concept to improve IM systems in construction projects (Chua, Godinot 2006). Chen et. al. (2008) explored cause factors of interface problems on offshore, commercial, and residential construction, with a multi-perspective approach (Chen, Reichard et al. 2008).

There are also many researchers working on developing more effective web based IM System platforms for the construction industry. Some of the related recent studies in the literature are explained briefly in the rest of the paragraph. Lin (2013) proposed a web-based platform to connect project participants for managing interface problems during the construction phase (Lin 2013). Ju and Ding (2015) developed an integrated interface model for metro equipment engineering to improve an IM system by changing it from traditional methods to a more standardized and structured web based interface management format (Ju, Ding 2015). Lin (2015) also developed a web based IM system that integrates three dimensional interface maps to BIM approach for engineers to improve physical interface information sharing and tracking during the construction phase for building projects (Lin 2015). Although there are many studies dealing with many aspects of IM system on the construction phase of the projects, there is still a knowledge gap for visualizing the IM system in the design phase.

Usage of IM Systems is growing in the construction industry lately. Although IM has a long history, it was not used in engineering and construction projects extensively, because of lack of necessary technological infrastructure and lack of common understanding on IM. Today, with the developments on the information and communication technologies, there are more engineering and construction projects that have adopted IM in different forms in their projects using in-house and commercial systems (Shokri 2014).

2.2 Building Information Modelling (BIM)

Building Information Modelling (BIM) technology which was introduced almost thirty years ago, is one of the most promising developments in the architecture, engineering, and construction (AEC) industry today (Eastman, Teicholz et al. 2008). Although the term “BIM” is very popular, there is still no single or widely accepted definition for BIM technology. The definition provided by the National Building Information Model Standard (NBIMS) as “a digital representation of physical and functional characteristics of a facility and it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward”, will be accepted as the BIM definition for this paper.

Improvements on the computer science and developments on the software platforms helped BIM technology to extend traditional 2D and 3D technical drawings into more intelligent visual modelling. Today schedule and cost data of the project can be connected to BIM model as 4^{th} and 5^{th} dimensions, and can be tracked visually. In the literature, there are numerous studies that deal with different aspects of BIM technology on construction projects, such as using BIM models for improving collaboration between project participants, reducing material waste, detecting clashes, creating energy efficient structures, controlling design changes, etc. (Meadati, Goedert 2008; Azhar, Carlton et al. 2011;Roh, Aziz et al. 2011; Singh, Gu et al. 2011;Wong, Fan 2013). Since BIM systems work with structured data, which can be easily ordered and processed, connections between BIM and other systems can be established.

When project team creates a BIM model of their project carefully, it would contain both geometric and engineering data of the project’s lifecycle (Tse, Wong et al. 2005; Azhar 2011; Ding, Zhou et al. 2012; Lin 2015; Zeng, Tan 2007). Therefore, it helps project stakeholders to visualize the details of the project, and helps them to make decisions concerning work methods (Chau, Anson et al. 2004).

3 Integration of BIM and IM systems

Integration of BIM and IM data and related information is a vital need for improved project monitoring and control and for more informed real-time decision making in large-scale complex projects. Today in many complex construction projects, IM and BIM systems are being used and managed separately. Connecting BIM systems' deterministic product management perspective and object-oriented approach with IM systems' process-oriented approach would provide a better understanding for managing the complexities associated with project uncertainties and risk in organizational structure, coordination, collaboration, and communication.

Generally, in complex construction projects project team start creating BIM model of the project before establishing its IM system. In the early stages of the design phase, a conceptual BIM model would be generated and would get more detailed during the project lifecycle, while an IM system would start in the design phase when work packages of the project are defined. BIM and IM systems are dynamic systems, since each systems' elements change, evolve, and sometimes are removed from the system. Especially in the design phases of the construction projects, many new elements would be added on the BIM model, while many of the existing elements could be edited or deleted in order to achieve a more detailed design. Likewise, numbers of the project participants and IPs change on the IM system during the project lifecycle. Generally, there are few project participants in the beginning of the project, while the number increases during the construction phase, and then it decreases at the end of the project. Also, interface points do not stay the same; they appear and disappear during the project, especially in the design phase. Therefore, an IM system expands and shrinks with the change in the number of the project participants and number of interface points during the project lifecycle.

Typically, in complex construction projects, most of the project participants would have read-only access to the main BIM model, where they can view the model and properties, but cannot change any features of the elements. By integrating both BIM and IM systems, project participants would also be able to see their IPs with their actual location on BIM model. In addition, they would be notified via both the IM system and the BIM model with color changes on the elements when there is a new IP related with their work package. The result is expected to be improved communications and alignment along with reduced requests for information, change requests, and rework.

4 Methodology

Connections can be created by using common features in BIM and IM systems such as the schedule, specifications, location and dimensions of the elements. One way of establishing the link between BIM and IM systems is using the IFC database of a BIM system. The properties of many objects in a BIM model can be reachable by using IFC files, and they can be used for connecting BIM elements with associated Interface Points in the IM system.

IFC is a building information model format developed by the BuildingSMART (formerly known as the International Alliance for Interoperability - (IAI)) with the aim of describing, sharing, and exchanging building data among different AEC/FM (Architecture, Engineering, Construction / Facilities Management) software applications (Azhar 2011). Many objects in a BIM model can be defined in IFC format which provides objects' actors, controls, groups, products, processes, and resources information as structured information. Although first releases of the IFC format were related with building projects, BuildingSMART also concentrated on creating common resources for infrastructure projects such as bridge, tunnel, road, and rail construction. The first IFC extension for infrastructure works was published recently, and there are ongoing projects for more extensions. Although the IFC domain does not contain all elements on a complex construction project today, by using these IFC infrastructure works extensions, some IPs would be connected to related BIM elements on the BIM model. This proposed idea is presented in Figure 1 with internal connections of both BIM and IM systems.

Establishing an IM System for a capital project needs a detailed effort in the beginning of the project. Initially, the project needs to be divided into work packages, disciplines, and areas. Then, each stakeholder needs to be linked to the related work packages. Also, project manager, interface manager, and technical manager information should be provided for each stakeholder, so they can be informed by any new action on the IM system related with their work package. When the IM system setup phase is finished, IPs and IAs of the project can be defined.

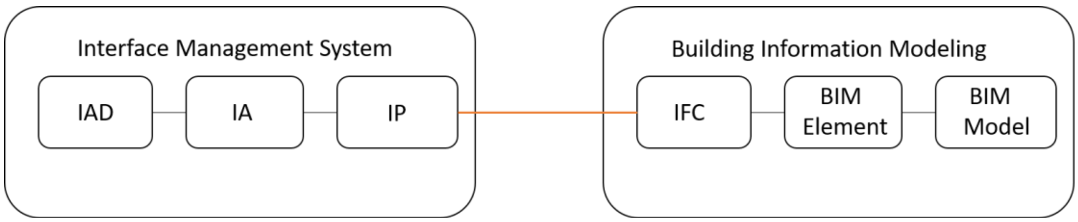


Figure 1: Connection between IM and BIM systems

In order to fill an IP form with any IM system available on the market today, users are required to define some mandatory information for generating a unique ID for that form. Mandatory information could include but would not be limited to entering title of the IP, and selecting project phase, discipline, area (location), leading work package, interfacing work package, etc. from dropdown menus. An example database connection behind an IP form can be seen in Figure 2.

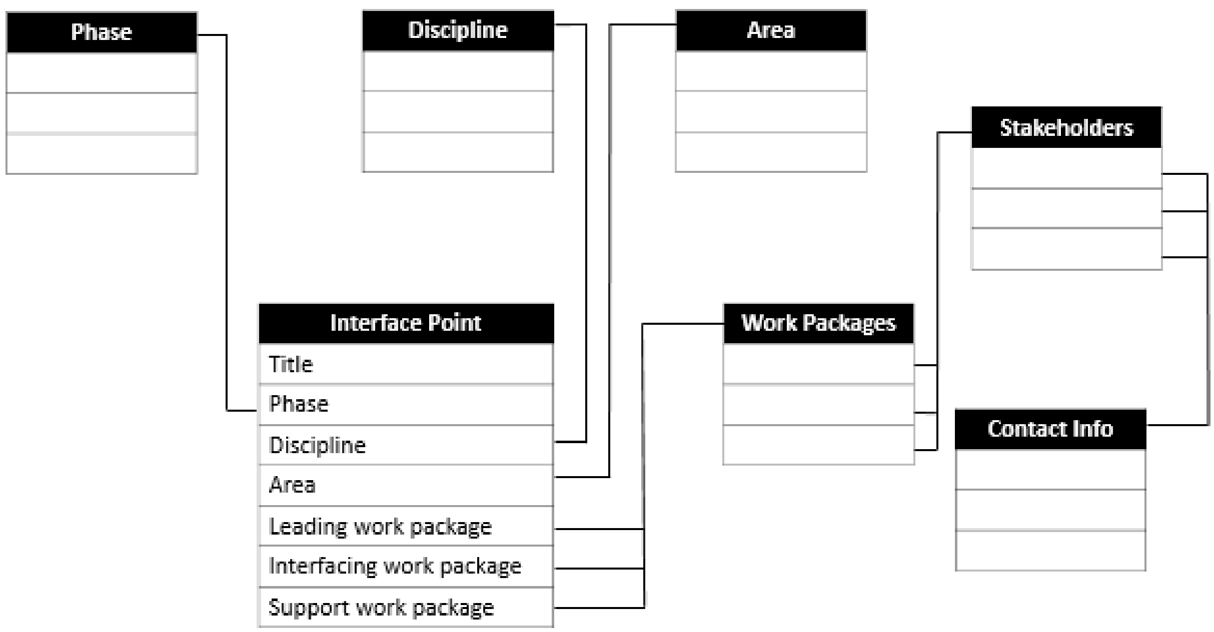


Figure 2: Example database connection behind Interface Point forms

Initial connections between BIM and IM systems using the proposed framework would be area (location) data, since that information is commensurate and consistent in both systems. In future implementations, facility system, and model layer may also be useful relations. Each element on the BIM model would have unique ID and area (location) data on the system that can be reachable by IFC format. By defining area on an IM system, related BIM elements would be reachable over the database. After adding initial mandatory information to the IP form, BIM model related section would be available on the form. On the BIM model related section, the user needs to select the related BIM element from a dropdown list. Also, by adding a visualization section add-in to the system, users would be able to see latest BIM model portion related to selected area on a pop-up screen. By choosing the related BIM element-ID from a dropdown menu, the connection between IP form and latest BIM model would be established. Then, related work packages would be chosen, and an IP form can be submitted. When an IP form is submitted to the system, related participants to those work packages would be informed via the IM system. Also, IP forms would be attached to the related element on the shared main BIM model. Thus, integration of BIM and IM systems would give the opportunity to project manager(s) and owner(s) to see current interface points between project participants with their actual locations or areas on the BIM model. The flow of the methodology is presented in Figure 3.

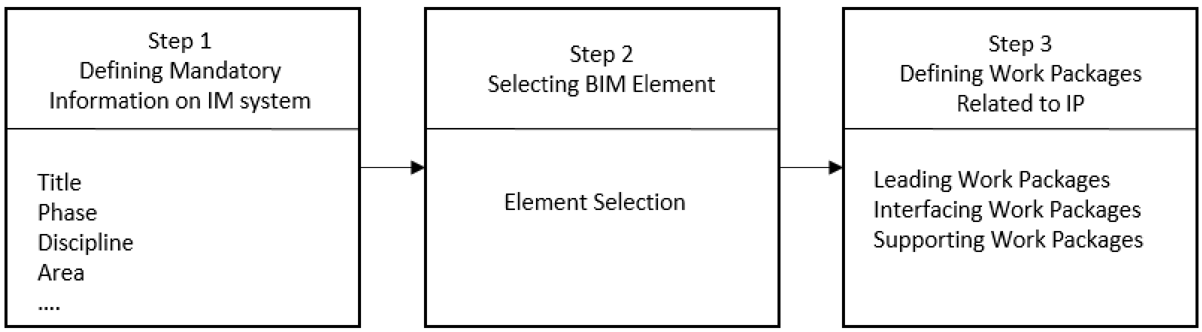


Figure 3: Flow chart of creating IP on integrated IM-BIM system

5 Case Study

This proposed framework can be further explained by using an LRT project example. Generally, LRT projects are built by consortiums, since these types of infrastructure projects are complex and require different project participants who have different specializations. Such consortiums create many interface points between participants. For example, stations would be subject to many interface points in an LRT project. Dimensions of the platforms are important for designing other systems in the project, therefore project participants need to agree on the dimensions of station platforms, and these agreements should be controlled properly. Height of the platform would be an interface point between Rolling Stock and Civil Works related project participants, since it would affect design of the train and door locations and vice versa. Similarly, wideness of the stations would be another interface point between Civil Works, Rolling Stock, and Track Works. Today, many LRT projects all around the world face problems that can be solved by establishing proper IM and BIM systems. Some of the common problems on stations are designing the platform lower than it should be, or designing train door heights that are different than the platform design, or building platforms shorter than the train length, or constructing stations narrower than trains can fit. Solving these types of problems in late phases of the project would result in extra costs and schedule problems.

In this hypothetical example, modelled after an existing project in Canada, an LRT project is going to be built by a consortium that consist of five stakeholders. Five work packages which are namely; Civil Works, Rolling Stock, Track Works, Signaling, and Infrastructure, are defined for the project. Each project participant on the consortium will be responsible for one work package. Interface point examples between these work packages on an LRT project are shown in Table 1.

Table 1: Examples for Interface points on LRT projects

Leader	Partner	Title of Interface	Interface Description
Rolling Stock	Civil Works	Platform Level	Details of cant and platform levels
Rolling Stock	Track Works	Vehicle Data	Vehicle data for dimensioning other systems
Signaling	Civil works	Signals	Requirements for implementation
Rolling Stock	Track works	Insulated Rail Joints	Location and quantity of Insulated Rail Joints
Employer	Rolling Stock	Design Restrictions	Height restrictions for dimensioning vehicles

According to the assumptions that have been made, there would be a conceptual BIM model of the LRT project in the early stages of the design phase, and each element on the model could be defined by IFC format. For this case study, first a conceptual BIM model of an LRT project is modelled on Autodesk Revit 2017. The route of the LRT project and an example station of the project are presented on Figure 4. Also, IM System software that has been developed by Coreworx Inc. will be used for this case study.

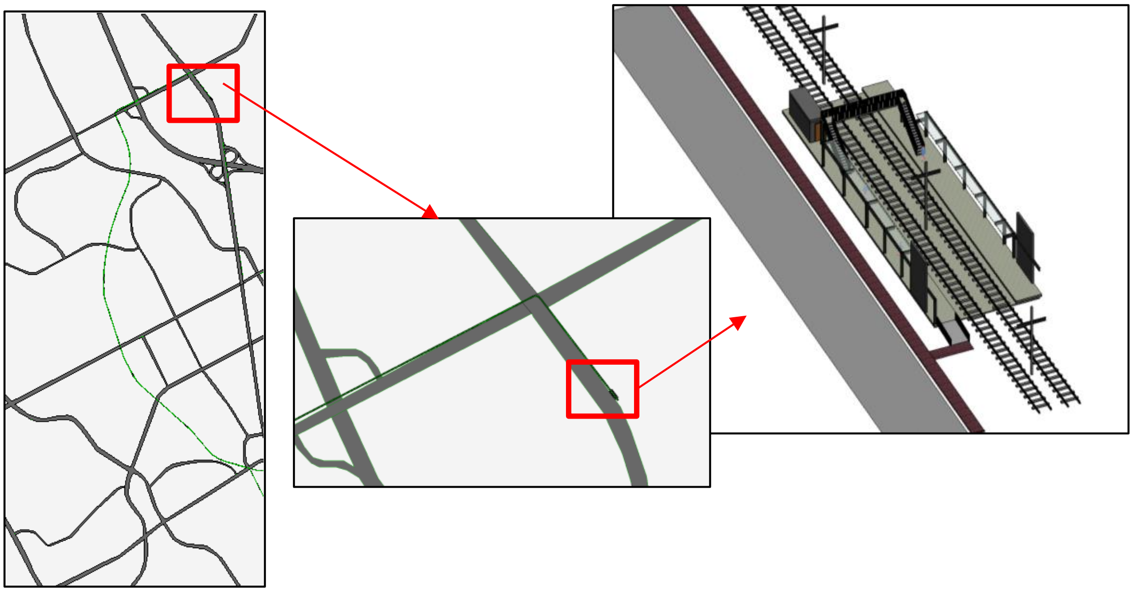


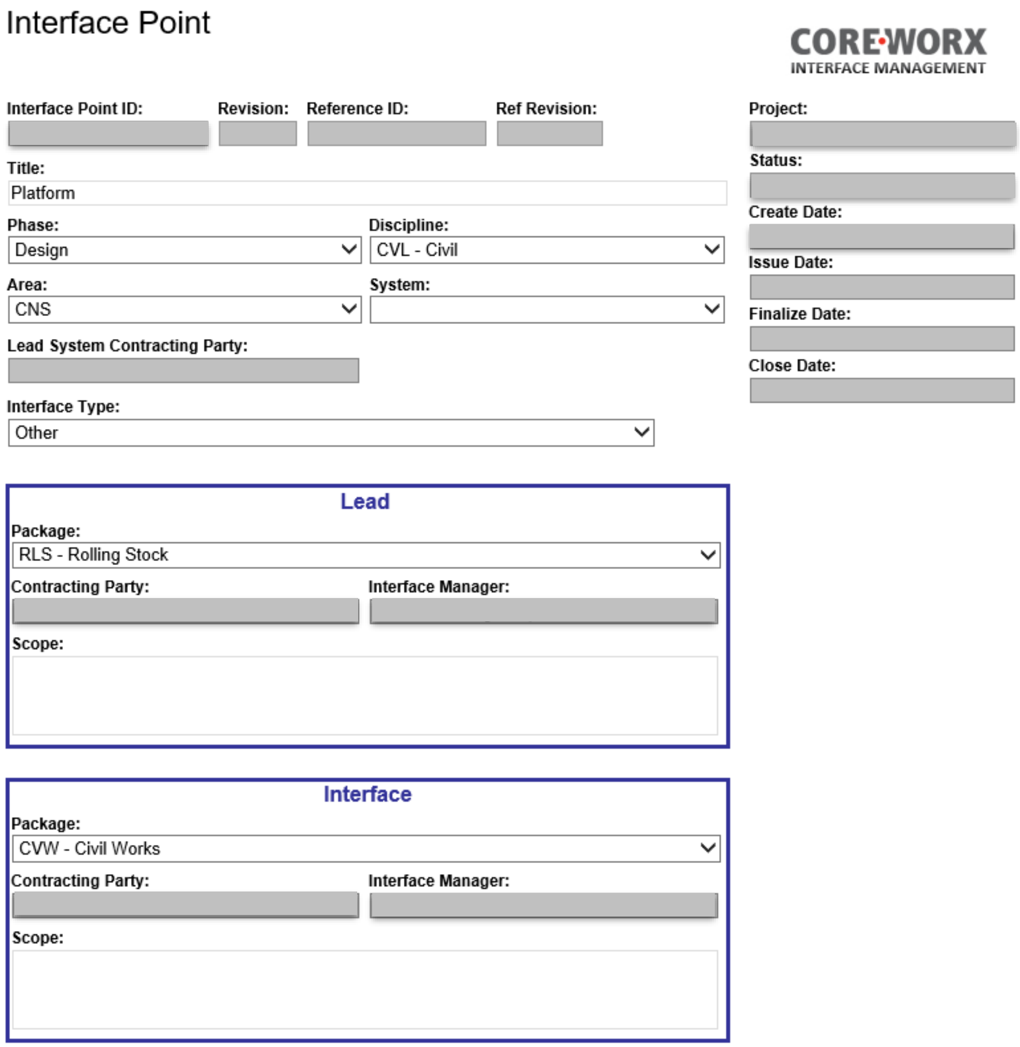
Figure 4: Conceptual model of an LRT project

In order to create the first interface point shown in Table 1 between Rolling Stock and Civil Works related stakeholders about the platform at the CNS Station, the IM manager of the Rolling Stock related project participant would need to follow the framework shown on Figure 3. As a first step, the user needs to define the IP title, which would be platform height in this example, then choose its phase, discipline, and area of the project from the dropdown menus. System information is not mandatory to define. Depending on the complexity of the project, discipline data can be divided into systems too.

When the Area option is selected from the dropdown menu, Step 2 would get activated, and a pop-up screen that contains the BIM model related to the selected area, would appear. In Step 2, the user would be requested to choose an element ID from the drop down menu. In this example, the user needs to select platform from the BIM element section. Selection would also be seen on the BIM model on the pop-up screen.

In the last step, the user needs to define work packages related with this IP. In this example the leading work package would be Rolling stock, while the interfacing work package is Civil works. When the IP form is submitted, the Interface manager of the Civil Works related project stakeholder would be informed on both the IM system and the BIM model. On the shared BIM model, the element would change its color to indicate that a new action is submitted to that element, and on the IM system users would receive notifications. Figure 5 shows the filled IP form on the Coreworx IM system for the case study. Grey rows on the IP form in Figure 5 would be automatically filled by the system when form is saved. Details of the second step of the methodology can be seen in Figure 6. The part shown in Figure 6 would be added on the current IP form prior to selecting leading and interfacing work packages, when the BIM and IM systems are fully integrated.

Most of the elements of this work process have been implemented. Complexity and scale is being built into the model system in order to facilitate validation of the effectiveness of the approach. Additional case studies are being developed to illustrate and test the breadth and efficiency of the approach.



Interface Point

CORE·WORX
INTERFACE MANAGEMENT

Interface Point ID: | Revision: | Reference ID: | Ref Revision:

Title:
Platform

Phase:
Design

Discipline:
CVL - Civil

Area:
CNS

System:

Lead System Contracting Party:

Interface Type:
Other

Project:

Status:

Create Date:

Issue Date:

Finalize Date:

Close Date:

Lead

Package:
RLS - Rolling Stock

Contracting Party: | Interface Manager:

Scope:

Interface

Package:
CVW - Civil Works

Contracting Party: | Interface Manager:

Scope:

Figure 5: Creating IP form on Coreworx IM system

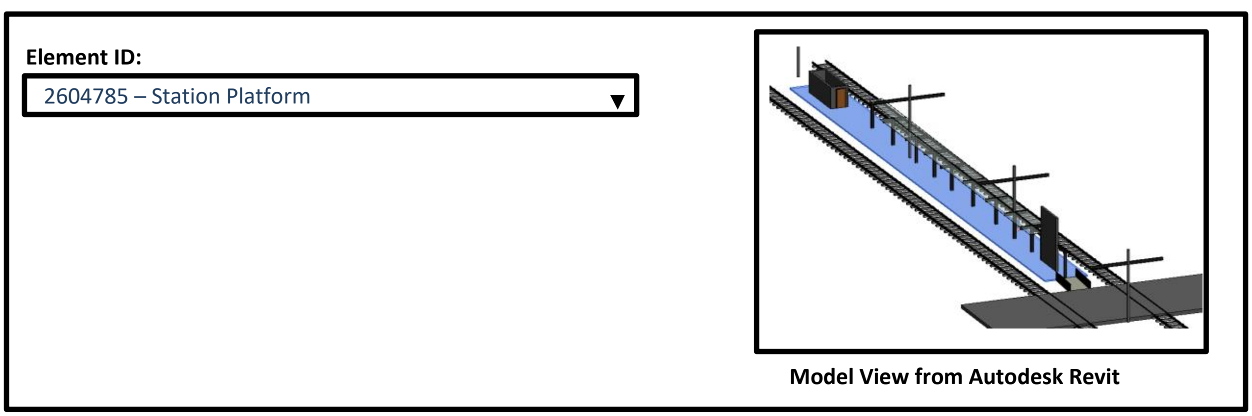


Figure 6: Selecting BIM element on IP form

6 Conclusion and Future Work

This paper presented a conceptual framework for integrating IM and BIM systems with partial functional validation. The presented framework is the first part of an ongoing research project related with project health and progress measurement. As the next step of the project, the proposed framework will be validated by using more detailed models, and then will be used for calculating project health. In order to validate the proposed framework, more realistic IM data from an LRT project needs to be collected, and a more realistic BIM model needs to be created.

In the proposed framework, location data of the elements is used for creating connections between two systems. The future work for this project contains, but is not limited to using other common information such as facility system and model layer, to create links between two systems. In the next steps of the related ongoing project, this framework can be applied in various phases of complex construction projects.

After having a fully functional validation of the proposed framework, it is expected to have a better coordination and communication between project participants over the interface related problems in the project definition and design phases. Integrating IM and BIM systems is expected to result in improved project control, communications and alignment along with reduced requests for information, change requests, and rework.

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